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Radio therapeutic techniques in medicine

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Abstract : Therapeutic application of radiation with teletherapy, sealed and open sources have been considered mainly from physical point. Types of sources utilized with their advantages and disadvantages have been mentioned. Megavoltage Isotopic Teletherapy units are found suitable for our country. Parameters such as origin, route of spread of disease, radiosensitivity, radiation-tolerance, homogeneity of radiation, sparing of tissues, fractionation of dose and integral dose are to be considered in choosing a particular radiation. Low-energy radiations give differential mass absorption coefficients in case of bone, muscle and soft tissues whereas in case of high-energy radiations, this coefficient varies very little.

Keywords : X-rays, gamma rays, radiation therapy.

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1. Introduction

Now-a-days very often we hear of radiation treatment which primarily, is applied for treatments with ionizing radiations. But looking at the radiation spectrum with low energy radio waves at one end and high energy gamma rays at the other end, there are various types of radiations, in between. The non-ionizing radiations like (i) ultraviolet, (ii) infra-red and (iii) short-wave diathermy also fall within this spectrum. But in this paper, emphasis is centered on the ionizing types of radiations. By ions we mean electrically neutral atoms changed into electrically charged, either positive or negative particles. In their passage through a media these ions are robbed off their energies either by formation of more ions or by excitation of other atoms. When an ion loses its energy, this energy is transferred to the media, through which it passes.

The ionizing types of radiations are used very often for the beneficial effects on human beings. But the ionizing radiations are also very harmful. Hence, one has to optimise and balance the beneficial effects with their deleterious effects.

The commonly used radiation is the X-ray radiation. The whole world population, except the extremely backward parts of this world, are now conversant with the use of X-rays for its diagnostic purposes in various modes.

The primary function of the X-rays, so far as diagnostic modalities are concerned is to study the anatomical features within the human bodies from outside. The X-rays are differentially absorbed into different body materials and the outgoing rays recorded in X-ray photographic films, present the composition of the inside of the body.

These are all static studies. But recent developments in this area have resulted in new techniques and apparatus to study the dynamic properties of the body also. Now with screening arrangements, one can study, how the different organs within the human body do respond to different types of investigations. This invisible type of radiation has proved to be of utmost use in medicine. But at the same time one must always be extremely cautious about its use, since exposure to these radiations though helpful for investigations are also at the same time harmful. When a pregnant woman is often radiographed to study the baby in the womb, it may result sometimes in that the baby may develop many malformations. Similarly, when eye is exposed to radiations, cataract is an usual complaint that seem to develope. Hence X-ray photography and screening are to be taken only when it is absolutely essential and that also must be done under the proper supervision of an expert radiologist, who would be in a position to select the particular type of X-radiation out of the radiations of different penetrating powers, resulting in minimal amounts of damages to the body. Apart from the patient in question, the operators must be fully protected so that they are not exposed to any unnecessary radiation.

2. Therapeutic application of radiation

2.1. *Treatment :*

In choosing a particular type of radiation for particular tumour, various clinical and physical factors are to be taken into considerations.

2.2. *Classification of radiation therapy :*

Source of radiations in therapeutic application can broadly be classified into following three headings :

(i) External beam therapy,

(ii) Sealed sources in surface, interstitial and intracavitary application and

(iii) Open sources (Internally administered, e.g. I-131, Au-198, P-32 etc.).

2.3. *External beam therapy :*

Regarding the external beam therapy, a few commonly utilized which may be grouped as follows, are

(a) X-rays of different energies from Grenz-ray therapy upto 20 KV to Mega Voltage therapy (1 MV and above). In between comes the contact therapy and Deep X-ray therapy.

(b) Gamma ray teletherapy : Ra-226, Cs-137, Co-60. Of these cobalt and cesium teletherapy are very common in our country at present.

(c) Particulate beam.

(i) Electron beams,

(ii) Proton beams,

(iii) Neutron beams and

(iv) Deuteron beams.

2.4. Sealed sources :

Now the sealed radioisotopic sources may broadly be classified as :

(a) Gamma ray sources : Ra-226, Cs-137, Co-60, Au-198, Ta-182 and etc.

(b) Beta ray sources : P-32, Sr-90+Y-90, RaD+RaE.

2.5. Physical and clinical factors governing choice of radiation for therapy :

To give a broad outline in choosing a particular type of radiation and the amount of radiation exposure the primary clinical factors governing the techinque of radiation treatment are :

(i) The site of origin and routes of spread.

(ii) Radiosensitivity of the primary lesion and its extensions (This defines the dose that is judged necessary to accomplish either tumour eradication for cure or growth restraint for palliation).

(iii) Radiation tolerance of the neighbouring organs to the contemplated dose and the patient as a whole to the procedure.

The physical factor of primary interest is the amount of energy deposition in the volume of the tissue concerned, giving rise to subsequent biological effects, direct or indirect. There are no cellular effects peculiar to differences in qualities of different types of ionizing radiations. However, on qualities there are differences in the physical distribution of radiation in tissues and rad for rad there are differences in their biological effectivenesses.

The differential absorption of radiations by different types of body tissues, such as muscles, bones and soft tissues, depending on their densities and atomic compositions and the factors like blood supply and consequent oxygen tension and the OER factor of a particular type of radiation are all to be taken into account in choosing a particular type of radiation. After the type of radiation has been decided upon, other paimary factors to be considered are :

(a) homogenity of the radiation at the site.

(b) sparing of healthy tissues as far as possible.

(c) fractionation of doses for its effects on the sensitivity of tumour cells and also for its effects on the reparative process of other healthy tissues in the parth of the beam.

(d) Integral does.

As for physical parameters, LET or Linear Energy Transfer value is of primary importance. This is the amount of energy deposited is tissue per unit length of the radiation beam. Higher LET values mean larger number of ion formation along the path of the beam, resulting in higher amount of energy deposition in tissues per unit path length and giving rise to higher degree of radio-biological response in the tissue concerned. Moreover, radio-biological experiments have shown that high LET value dense tracks, produced by heavy particles like protons, alphas and deuterons produced a greater biological effect than the same energy absorption by low LET tracks given by electrons, photons, etc. This means that particles such as neutrons, since they produce ionizing particles like, protons, have a higher RBE, i.e. Relative Biological Effectiveness than electrons. Fast neutrons have an extra advantage that the OER is about 1.7 (against 2.7 for X-rays) so that anoxic and oxygenated cells should react nearly in the same way to neutrons.

2.6. Radio biolcgical effectiveness (RBE) :

The following chart would give us an idea about the dependence of RBE values on the different types of radiations and on their energies and coesequent LET values :

Type	Energy	Initial LET (KeV/Micron)	RBE
Co-60 Gamma rays	1.1 MeV	0.2	1
X-rays	250 KeV	1.0	
	10 KeV	2.0	
	8 KeV	2.8	1
	250 Kvp, usual distribution	3.5 Average	1.0
S-25 Beta rays	46 KeV Max	0.7	1 to 2
Electrons	1 to 2 MeV	0.2	1 to 2
Protons	0.9 MeV	30.0	8 to 10
	8.4 MeV	5.5	
Fast neutrons	0.1 to 10 MeV		10
Slow neutrons	Less than 100 MeV		2 to 5
Alphas	5.3 MeV	90.0	
	12.0 MeV	50.0	
	38.0 MeV	20.0	20 to 10
Fission recoil	65 MeV	7000	(200 ?)

In general, what is observed from the above chart that RBE increases with LET values, although for very high values of LET, RBE may decrease somewhat. Here mention must be made about the fact that it is extremely difficult to measure the RBE values accurately from a given radiation beam, since inspite of the factor that time dose relationship be kept constant for two cases, there are obvious differences in energy distribution in a tissue at the cellular level. RBE is defined as the ratio of the absorbed dose in rads of X-rays or gamma rays (of a specified energy) to that of the rads of the given radiation having the same biological effect. The value of the RBE for a particular type of nuclear radiation, e.g. alpha or beta particles or neutrons, depends upon a number of factors such as the energy of the radiation and the kind and degree of biological damage and also on the nature of the organs or tissue under consideration. The unit 'rem' has been defined to measure the extent of biological injury, of a given type, that would result from the absorption of radiation and is the product of absorbed dose i.e. rads and RBE factor. Hence, Dose in rems = Dose in rads × RBE. Or in other words 'rem' can be regarded as the unit for biological dose.

2.7. Clinical situation :

In clinical situations, in which many types of tissues are involved in the volume of interest a single value of RBE for a particular type and energy of radiation is to be taken into account for treatment purpose. Inspite of these many uncertainities, it is of general experience that a given dose of radiations in 1 to 23 MeV range is about 85% as damaging as a similar dose of medium voltage radiations (hvl = mm cu) of 200 Kvp. Hence, a 15% higher dose in case of megavoltage radiations is required than that of medium voltage radiations if the same cancerocidal effect is to be expected. Obviously, this value is not applicable to energies beyond this range or to irradiation with particles.

With low energy X-rays the differential absorption in bones, tissues and muscles are to be considered because of prominent photoelectric effect at these regions. But at higher energies (200 KeV to 10 MeV), compton effect alone predominates and the amount of absorption is nearly same in all three materials. Even with high energy X-ray beams in the megavoltage region, where the units are quite complex, the primary difficulty is with the heterogeneity of the X-ray beam, whereas the beams coming from radioisotopic sources are composed either of a single or a few well-defined energy beams. If we look at a X-ray spectrum we find, that X-rays of all energies upto maximum are present, and even with sufficient amount of filtration, at the cost of output, homogenity cannot be achieved. Moreover, the low energy X-rays, accompanying the rays coming out of high energy units do contribute very large portion of the total energy obtained and these low energy components, do damage the in-between tissues to a great amount when a tumour bed at a certain considerable depth is to be treated.

Since, with the development of atomic energy, large scale production of various radioisotopes are available and since the energies of the beam are not subject to fluctuation with power supply and etc. it is better for us to use isotopic sources than machine produced X-rays.

3. Advantage of megavoltage

About the advantages of megavoltage radiation, we may touch a few salient points, of which skin sparing effect and less integral dose are most important.

A. With high energy beams, the maximum of the dose occurs at a depth within the skin, depending on the energy of the beam. In case of cobalt radiations, having energy of 1.25 MeV (average), this max occurs at depth of 5 mm of skin, because of secondary electron build up factor, whereas with conventional X-rays of 250 Kvp this maximum occurs at the surface of the skin. As a result the conventional X-rays do damage the epidermis and corium, where the capillaries are situated, to the maximum amount when a deep sitted tumour is treated. But with Co-60 beams, the maximum ionization occurs at a depth of 5 mm where only the elastic tissue bundles, which extend beyond the corium are situated. This enables doses of 5000 to 6000 rad to be given in single field by suitable fractionation with only an epilative or mild tanning of the skin. Reduction of skin reactions is a very important aspect of radiation therapy.

B. The second important advantage of high energy beams, particularly monoenergetic, is the achievement of uniformity in relative mass absorption in bones, muscular tissues and fat tissues. The high relative bone absorption in the case of low Kv X-rays increases the energy delivered to the capillaries in the Haversian canal, and the osteocytes, thus leading to bone necrosis. Further, it reduced the dose to the soft tissues which are situated behind the bone in the path of the beam.

High energy radiations which can be easily obtained from isotopic sources, give a much lower integral dose to tumour dose ratio than low Kv X-rays, which are also demonostrable by means of graphs. The integral dose associated with the therapeutic doses for a particular tumour bed with low Kv X-rays are often so high that it is impossible to achieve the tumour dose avoiding systematic reactions, which becomes the prohibitive factor in giving further doses.

Moreover, the geometrical definition in case of low Kv X-rays are not as good as in the case of high energy radiations. In case of low energy radiations the scatterings are more towards the sides, whereas in case of high energy radiations the scatterings are more towards the frontal direction. As a result, in case of high energy radiations the isodoses extends very little towards the sides, compared to the low energy radiations.

C. Another important factor with isotopic sources are the stability of the energy of the beam. In case of machine produced X-rays, the energies are dependent on the fluctuation in the voltage or any other variations in the machine, but in case of isotopic sources, the energies of the beam coming out are always having the fixed energies.

D. Finally, it may be mentioned here that the isotopic sources are relatively cheaper than machine produced X-rays beams, though the problem of source replacement always remains. Another disadvantage with isotopic sources are that the source always emits gamma rays irrespective of the fact that whether the machine is in "on" or "off" position and naturally more elaborate arrangement about protection is to be made and also for repairing purposes inside, at times it may be required to take out the source, which is rather a complex and at the same time costly procedure.

4. Choice of radiation source

The primary criterion to choose a particular radioisotope is that the source must have fairly long half-life, so that the problem of very frequent replacement of source can be avoided. Other factor to be considered in this respect is that the gamma rays should have high energies, so that deep-seated tumours can be treated and also that the isotope would have high specific activity, which means, the source size should be small, so as to reduce the penumbra of the outcoming beam.

Now coming to the equipments most frequently used now-a-days for patients treatemnt in radiotherapy, the following may by mentioned :

(i) Contact therapy machine.

(ii) Conventional X-rays machines with adjustable voltages.

(iii) Cesium-teletherapy machines.

(iv) Cobalt-teletherapy machines.

(v) Linear accelerators for gamma rays only.

(vi) Linear accelerators for both gamma rays and electron rays of various energies.

(vii) Betatrons.

In our country (i) to (iv) are mostly utilized, though only a very few of the institutions have the facility of utilizing one or another of the rest.